Process Study of Oceanic Responses to Typhoons using Arrays of EM-APEX Floats and Moorings

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LONG-TERM GOALS

Our long-term scientific goals are to understand the upper ocean dynamics, to understand the coupling between ocean and atmosphere via air–sea fluxes, and to quantify the mechanisms of air–sea interactions. Our ultimate goal is to help develop improved parameterizations of air–sea fluxes in ocean–atmosphere models, parameterization of small-scale processes in the upper ocean and in the stratified interior.

OBJECTIVES

The energy of tropical cyclones is derived from the ocean via the air–sea flux. The oceanic heat content in the mixed layer and the air–sea enthalpy flux play important roles in determining the typhoon's maximum potential intensity, structure, energy, trajectory, and dynamic evolution. Forced by tropical cyclones, the most energetic oceanic processes are surface waves, wind-driven current, shear and turbulence, and inertial currents. In order to understand the dynamics and structures of tropical cyclones, one needs to understand these oceanic processes and quantify their effects on the air-sea flux during the passage of cyclones. Small-scale and meso-scale oceanic processes also play crucial roles in determining the recovery of oceanic conditions after their responses to tropical cyclones. In tropical cyclones, these processes are the least understood primarily because of the paucity of direct field observations, consequently leading to large uncertainties in air–sea fluxes.

For this project, we designed an observational experiment that will provide in-situ oceanic observations in the western Pacific on the paths of tropical cyclones to understand the coupled dynamics in a wide-range of oceanic and atmospheric conditions. Our broad focus is on surface waves, inertial waves, shear instability, internal waves, and meso-scale eddies before, during, and after the tropical cyclones. Primary objectives of this project are 1) to provide observations of oceanic responses to a wide range of atmospheric wind forcing including tropical cyclones, 2) to provide observations of

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14. ABSTRACT
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effects of oceanic conditions on the strength of tropical cyclones, and 3) to help provide better parameterization schemes for air–sea fluxes, especially in the tropical cyclone extreme wind forcing regime, and for interior mixing.

APPROACH

In 2009 we will deploy an array of four ADCP-CTD or ADCP-CT moorings in the western Pacific. The surface buoy moorings will be equipped with a meteorology package. Near real-time meteorology observations will be transmitted via Iridium satellite every 8 hrs. The mooring array will be maintained until the end of typhoon season in 2010. During the 2010 typhoon season, we will deploy EM-APEX floats on the paths of western Pacific typhoons. EM-APEX floats will be deployed either by aircraft or from research vessels, depending on the availability of aircraft. EM-APEX floats will transmit near-real time observations of velocity, temperature, salinity, and GPS position via Iridium satellite.

WORK COMPLETED

In June 2008 Dr. David Tang at National Taiwan University deployed two ATLAS moorings in the western Pacific as a part of pilot study. We provided two Long Rangers and 14 SBE39 temperature sensors to be equipped on the two moorings, each with one Long Ranger and 7 SBE39 sensors. Unfortunately, the first buoy sank and all instruments on the mooring line were lost. The second mooring was deployed at ~127.5 E, 20.5 N. Because of the loss of the first mooring, the Long Ranger was not deployed on the second mooring.

RESULTS

The pilot mooring (Figure 1) was deployed in June 2008 with a chain of seven SBE39 temperature sensors (APL/NTU), weather package (NTU) and a rain gauge (CNU). Two typhoons have passed this pilot mooring between June and September 2008. A satellite image of typhoon Fung-Wong after passing Taiwan taken on 26 July 2008 is shown in Figure 1. Weather observations were transmitted via Iridium satellite providing near real-time data (8-hr delay, maximum). Three more moorings (semi-transparent buoys in the left panel) will be deployed in 2009. These moorings will be maintained until the end of the 2010 typhoon season. In 2010 all moorings will be equipped with ADCPs to take vertical profiles of velocity observations.

Up until early September 2008, the mooring has collected nearly 3 months of observations (Figure 2). Typhoon Fung-Wong passed by our pilot mooring on July 25 causing ~20 hPa air pressure drop and –4^{o}C air temperature decrease. The maximum wind speed recorded on the mooring reached 50 kt. Weather data were collected at a 5-min sampling interval and transmitted every 8 hr. Wind direction and solar radiation were also collected, but not shown.

Four days after Fung-Wong passed the mooring, satellite sea surface temperature, a TRMM (Tropical Rainfall Measuring Mission) Microwave Imager (TMI) product, shows the extent of the cold wake (Figure 3). It is stronger on the right of the typhoon track, as expected. The intensity of the cold wake was weakening at the time of the of the satellite observation. Although the mooring was on the left of the typhoon track, the satellite SST shows significant cooling at the mooring site. We will compare temperature-chain measurements, to be recovered on April 2009, with satellite temperature observations.

One striking feature of the oceanic response to Fung-Wong is the appearance of a pool of cold water northeast of Taiwan on the East China Sea shelf. The cold dome northeast of Taiwan is thought to be associated with the Kuroshio subsurface water intrusion onto the shelf of East China Sea. Here, it appears to be caused by the passing typhoon.

IMPACT/APPLICATION

The oceanic heat content could significantly modulate the strength of the passing tropical cyclones. Similarly, tropical cyclones could cause strong oceanic responses, e.g., forcing surface waves, inertial waves, and deepening surface mixed layer, etc. To improve the skill of modeling oceanic responses to tropical cyclones and prediction of tropical cyclones, we need to understand the small-scale processes responsible for the air-sea fluxes and interior mixing and the meso-scale oceanic processes that modulate the background oceanic heat content. The present field experiment will provide direct observations of oceanic responses forced by tropical cyclones and recovery after forcing, and help understand the dynamics of small-scale and meso-scale oceanic processes. These observations will help improve the prediction skills of oceanic and atmospheric models in high wind regimes.

RELATED PROJECTS

Energy Budget of Nonlinear Internal Waves near Dongsha (N00014-05-1-0284) as a part of NLIWI DRI: In this project, we study the dynamics and quantify the energy budget of nonlinear internal waves (NLIWs) in the South China Sea using observations taken from two intensive shipboard experiments in 2005 and 2007 and a set of nearly one year of velocity–profile measurements taken in 2006–2007 from three bottom mounted ADCPs across the continental slope east of Dongsha Plateau in the South China Sea. Results of NLIWI DRI will help improve our understanding of the dynamics of internal waves and their effects on the turbulence mixing in the upper ocean.

Study of Kuroshio Intrusion and Transport using Moorings, HPIES and EM-APEX Floats (N00014-08-1-0558) as a part of QPE DRI: The primary objectives of this observational program are 1) to quantify and to understand the dynamics of the Kuroshio intrusion and its migration into the southern East China Sea (SECS), 2) to identify the generation mechanisms of the Cold Dome often found on the SECS, 3) to quantify the internal tidal energy flux and budgets on the SECS and study the effects of the Kuroshio front on the internal tidal energy flux, 4) to quantify NLIWs and provide statistical properties of NLIWs on the SECS , and 5) to provide our results to acoustic investigators to assess the uncertainty in the acoustic prediction. Results of this DRI program will help understand oceanic physical processes on the southern East China Sea, e.g., the cold dome. Typhoons may modulate the Kuroshio, the Kuroshio intrusion, and other oceanic processes and result in cold pools on the continental shelf of the southern East China Sea (Figure 3).

HONORS/AWARDS/PRIZES

Gledden Sr. Visiting Fellowship at U. Western Australia (Sanford)
SecNav/CNO Chair in Oceanographic Sciences (Sanford)
IEEE/OES Distinguished Technical Achievement Award (Sanford)

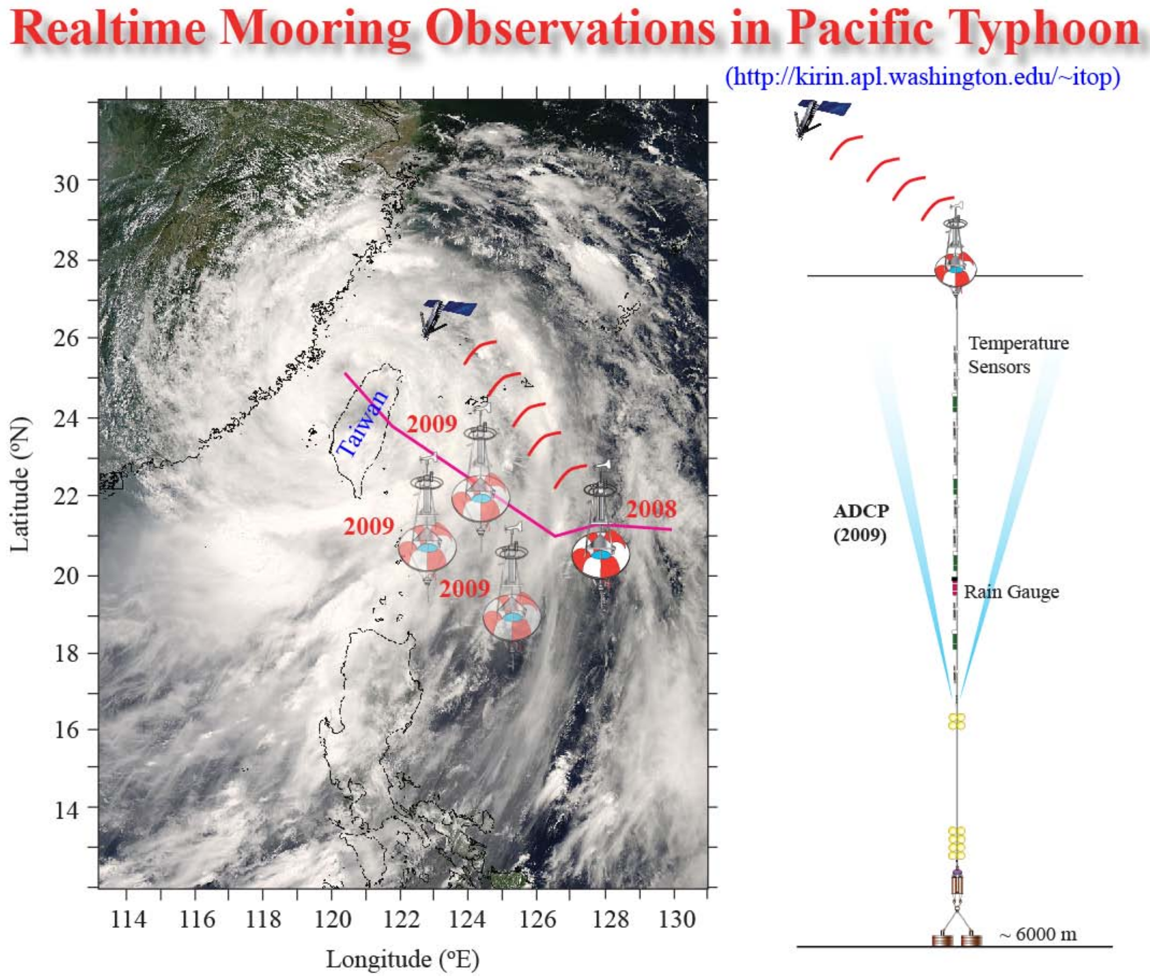

Figure 1: The satellite image of typhoon Fung-Wong after passing Taiwan in July 2008 (left panel) and configuration of ADCP temperature chain mooring. The magenta curve illustrates the track of Typhoon Fung Wong. The position of the pilot mooring is labeled with the ATLAS surface buoy. Three semi-transparent ATLAS surface buoys illustrate the other three moorings to be deployed in 2009.

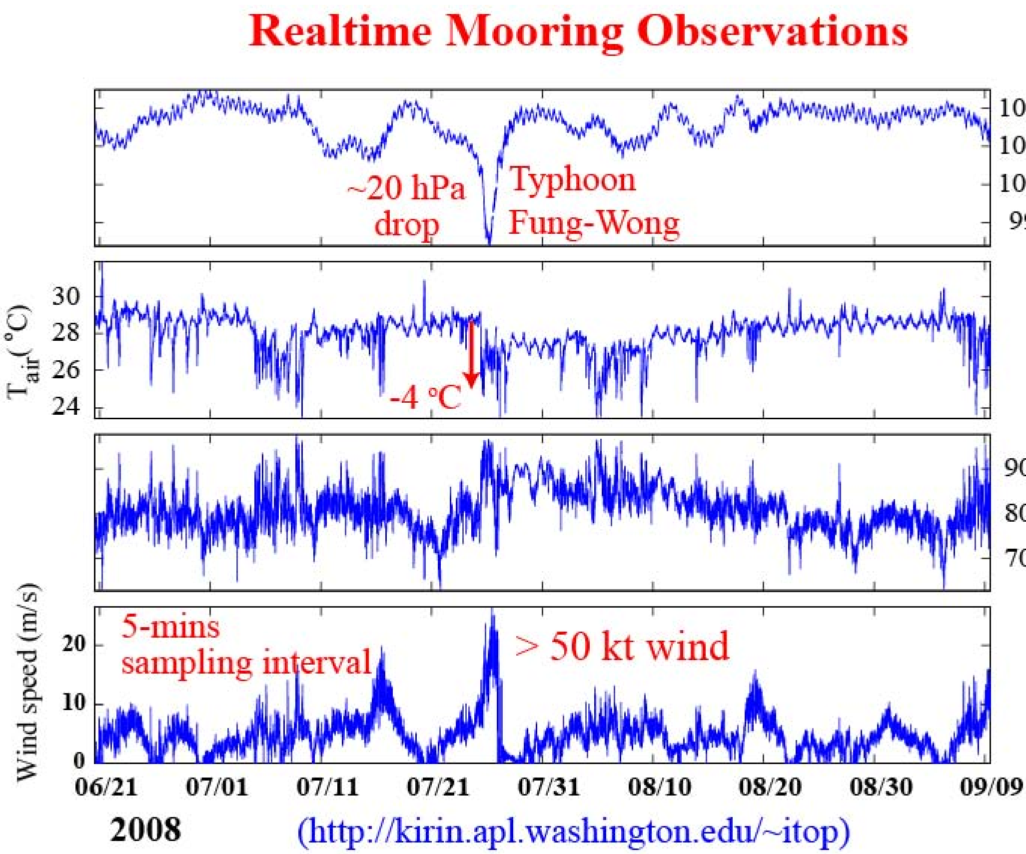

Figure 2: Time series of observations of atmosphere pressure, air temperature, relative humidity, and surface wind speed measured on the pilot mooring. Effects of typhoon Fung-Wong are illustrated. Meteorology measurements are taken at a 5-min sampling interval and transmitted via Iridium satellite every 8 hours.

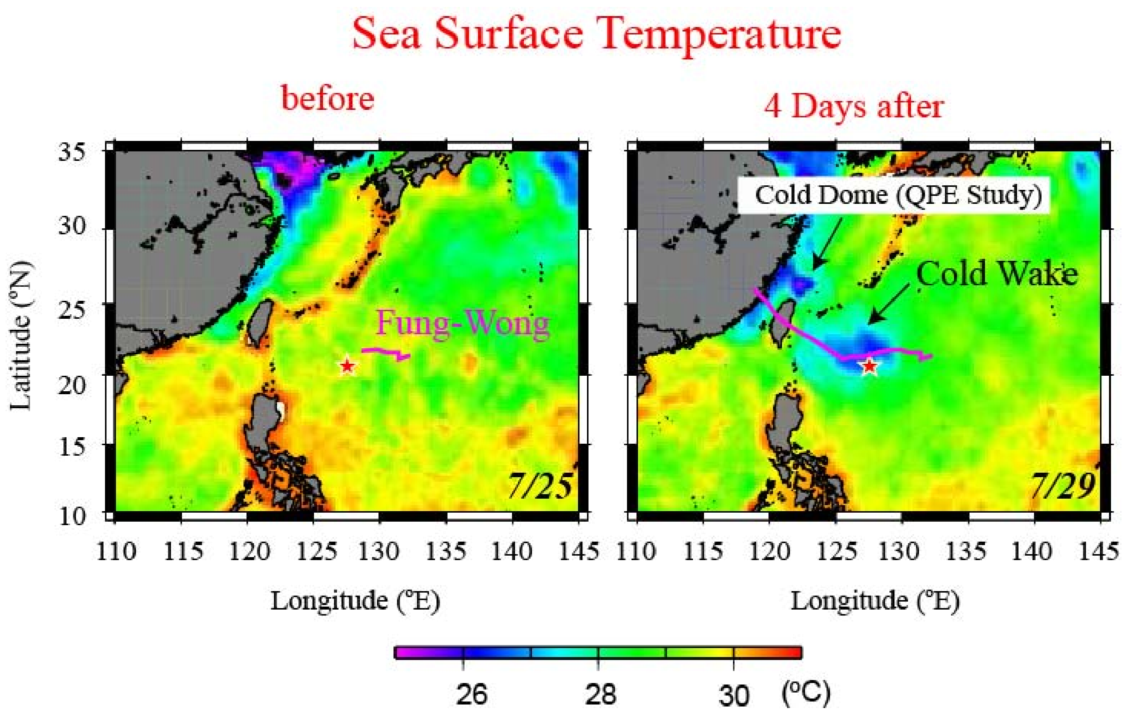

Figure 3: Satellite, TMI, derived sea surface temperature before typhoon Fung-Wong passing our pilot mooring (red star) and 4 days after passing the mooring. Cold wake along the typhoon track and the cold pool on the East China Sea are labeled by arrows. The cold pool on the East China Sea coincides with the Cold Dome which is the focus of the QPE DRI.